ANIMADVERSIONS

UPON

Mr. HOBBES's *PROBLEMATA*

DE

VACUO.

By the Honourable

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PREFACE.

UPON *the coming abroad of* Mr. Hobbes's Problemata Physica, *finding them in the hands of an Ingenious Person, that intended to write a Censure of them, which several Employments private and publick have, it seems, hinder'd him to do; I began, as is usual on such occasions, to turn over the leaves of the Book, to see what particular things it treated of. This I had not long done before I found, by obvious passages in the* third Chapter, *or Dialogue, as well as by the Title, which was* Problemata de Vacuo, *that I was particularly concern'd in it; upon which I desired the Possessor of the Book, who readily consented, to leave me to examin that* Dialogue, *on which condition I would leave him to deal with all the rest of the Book. Nor did I look upon the Reflections I meant to make as repugnant*

to the Reſolutions I had taken againſt writing Books of Controverſie, ſince the Explications, Mr. Hobbes *gave of his Problems, ſeem'd to contain but ſome Variations of, or an Appendix to, his Tract* De Natura Aeris, *which, being one of the two firſt pieces that were publiſhed againſt what I had written, was one of thoſe that I had expreſly reſerv'd my ſelf the liberty to anſwer. But the* Animadverſions *I firſt made upon Mr.* Hobbes's Problems De Vacuo, *having been caſually miſlaid e're they were finiſhed; before I had occaſion to reſume my task, there paſt time enough to let me perceive, that his Doctrine, which 'twill eaſily be thought that the* Vacuiſts *diſapproved, was not much reliſhed by moſt of the* Pleniſts *themſelves, the moderneſt* Peripateticks *and the* Carteſians; *each of them maintaining the* Fullneſs *of the World, upon their own grounds, which are differing enough from thoſe of our Author, the natural Indiſpoſition I have to Polemical Diſcourſes, eaſily perſwaded me to let alone a Controverſie, that did not appear needful: And I had ſtill perſiſted*

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in my ſilence, if Mr. Hobbes *had not as 'twere ſummon'd me to break it by publiſhing again his* Explications, *which in my* Examen *of his Dialogue* De Natura Aeris *I had ſhewn to be erroneous.*

And I did not grow at all more ſatisfied, to find him ſo conſtant as well as ſtiff an Adverſary to interſpers'd Vacuities, *by comparing what he maintains in his Dialogue* De Vacuo, *with ſome things that he teaches, eſpecially concerning God, the Cauſe of Motion, and the Impervioufneſs of Glaſs, in ſome other of his Writings that are publiſhed in the ſame Volume with it. For ſince he aſſerts that there is a God, and owns Him to be the Creator of the World; and ſince on the other ſide the Penetration of Dimenſions is confeſſed to be impoſſible, and he denies that there is any* Vacuum *in the Univerſe; it ſeems difficult to conceive, how in a World that is already perfectly full of Bodie, a* Corporeal *Deity, ſuch as he maintains in his* Append. ad Leviath. cap. 3, *can have that acceſs even to the minute parts of the Mundane Matter, that ſeems requiſite to the Attributes and Operations that*

belong to the Deity, in reference to the World. But I leave Divines to consider what Influence the conjunction of Mr. Hobbes's *two Opinions, the Corporeity of the Deity, and the perfect Plenitude of the World, may have on Theology. And perhaps I should not in a Physical Discourse have taken any notice of the proposed Difficulty, but that, to prevent an Imputation on the Study of Natures Works, (as if it taught us rather to degrade than admire their Author,) it seem'd not amiss to hint* (in transitu) *that Mr.* Hobbes's *gross Conception of a Corporeal God, is not only unwarranted by* sound *Philosophy, but ill befriended even by* his own.

My Adversary having propos'd his Problems by way of Dialogue *between* A. *and* B; *'twill not, I presume, be wonder'd at, that I have given the same form to my Animadversions; which come forth no earlier, because I had divers other Treatises, that I was more concern'd for, to publish before them.*

But because it will probably be demanded, why on a Tract that is but short,

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my Animadverſions ſhould take up ſo much room? It will be requiſite, that I here give an account of the bulk of this Treatiſe.

And firſt, *having found that there was not any one Problem, in whoſe Explication, as propos'd by Mr.* Hobbes, *I ſaw cauſe to acquieſce, I was induc'd for the Readers eaſe, and that I might be ſure to do my Adverſary no wrong, to tranſcribe his whole Dialogue, bating ſome few Tranſitions, and other Clauſes not needful to be transferr'd hither.*

Next, I was not willing to imitate Mr. Hobbes, *who recites in the Dialogue we are conſidering the ſame Experiments that he had already mentioned in his Tract* De Natura Aeris, *without adding as his own (that I remember) any* new *one to them. But my unwillingneſs to tire the Reader with bare*

Credo, (*ſays Mr.* Hobbes *in his* Dialogus Phyſicus:) Nam motus hic Reſtitutionis, Hobbii eſt, & ab illo primo & ſolo explicatus in Lib. de Corpore, cap. 21. Art. 1. Sine qua Hypotheſi, quantuſcunque labor, ars, ſumptus, ad rerum Naturaliū inviſibiles cauſas inveniendas adhibeatur, fruſtra erit. *And ſpeaking of the Gentlemen (to whom it were not here proper for me to giv*

De Nat. Aeris, p. 13.

give Epithets) *that us'd to meet at* Gresham-College, *and are known by the Name of the* Royal Society, *he thus treats them and their way of Inquiring into Nature*: Conveniant, ſtudia conferant, Experimenta faciant quantum volunt, niſi & Principiis utantur meis, nihil proficient.

A. Fateris ergo nihil hactenus à Collegis tuis promotam eſſe ſcientium Cauſarum Naturalium, niſi quod Unus eorum Machinam invenerit, quâ motus excitari Aeris poſſit talis, ut partes Sphæræ ſimul undiquaque tendant ad Centrum, & ut Hypotheſes Hobbianæ, antè quidem ſatis probabiles, hinc reddantur probabiliores.

B. Nec fateri pudet; nam eſt aliquid prodire tenus, ſi non datur ultra.

A. Quid *tenus*? quorſum autem tantus apparatus & ſumptus Machinarum factu difficilium, ut eatenus tantum prodiretis quantum

bare Repetitions of the Arguments I employ'd in my Examen *of that Tract, invited me to endeavour to make him ſome amends for the exerciſe of his patience by inſerting, as occaſion was offer'd, five or ſix new Experiments, that will not perhaps be ſo eaſily made by every Reader that will be able (now that I have perſpicuouſly propos'd them) to underſtand them.*

And laſtly, ſince Mr. Hobbes *has not been content to magnifie himſelf and his way of treating of Phyſical matters, but has been pleas'd to ſpeak very ſlightingly of Experimentarian Philoſophers (as he ſtiles*

ſtiles them) in general, and, which is worſe, to diſparage the making of elaborate Experiments; I judg'd the thing, he ſeem'd to aim at, ſo prejudicial to true and uſeful Philoſophy, that I thought, it might do ſome ſervice to the leſs knowing, and leſs wary, ſort of Readers, if I tryed to make his own Explications enervate his Authority, and by a ſomewhat particular Examen *of the Solutions he has given of the Problems I am concern'd in, ſhew, that 'tis much more eaſie to undervalue a frequent recourſe to Experiments, than truly to explicate the* Phænomena *of Nature without them. And ſince our Author, ſpeaking of his* Problemata Phyſica, *(which is but a ſmall Book) ſcruples not to tell His Majeſty, to whom he dedicates them, that he has therein compriſed (to ſpeak in his own terms)* the greateſt and moſt probable part

tum ante prodierat Hobbius? Cur non inde potiùs incepiſtis ubi ille deſiit? Cur Principiis ab illo poſitis non eſtis uſi? Cumque Ariſtoteles rectè dixit, ignorato motu ignorari Naturam, &c.

— Ad Cauſas autem, propter quas proficere ne paululum quidem potuiſtis, nec poteritis, accedunt etiam aliæ, ut odium Hobbii, &c.

part of his Physical Meditations; and since by the alterations, he has made in what he formerly writ about the Phænomena of my Engine, he seems to have design'd to give it a more advantageous form: I conceive, that by these selected Solutions of his, one may, without doing him the least injustice, make an estimate of his way of discoursing about Natural things. And though I would not interess the credit of Experimentarian Philosophers in no considerabler a Paper than this; yet if Mr. Hobbes's Explications and mine be attentively compared, it will not, I hope, by them be found, that the way of Philosophising he employs, is much to be preferr'd before that which he undervalues.

ANIMADVERSIONS

UPON

Mr. HOBBES's

Problemata de VACUO.

A. MAy one, without too bold an inquiſitiveneſs, ask, what Book you are reading ſo attentively?

B. You will eaſily believe you may, when I ſhall have anſwer'd you, that 'twas Mr. *Hobbes*'s lately publiſh'd Tract of Phyſical Problems, which I was peruſing.

A. What progreſs have you made in it?

B. I was finiſhing the third Dialogue or Chapter when you came in,

and finding my ſelf, though not named, yet particularly concern'd, I was peruſing it with that attention which it ſeems you took notice of.

A. Divers of your Experiments are ſo expreſly mention'd there, that one need not be skill'd in decyphering to perceive that you are intereſſed in that Chapter, and therefore ſeeing you have heedfully read it over, pray give me leave to ask your Judgment, both of Mr. *Hobbes*'s Opinion, and his Reaſonings about *Vacuum*.

B. Concerning his Opinion, I am ſorry I cannot now ſatisfie your Curioſity, having long ſince taken, and ever ſince kept, a Reſolution to decline, at leaſt until a time that is not yet come, the declaring my ſelf either for or againſt the *Pleniſts*. But as to the other part of your Queſtion, which is about Mr. *Hobbes*'s Arguments for the abſolute Plenitude of the World, I ſhall not ſcruple readily to anſwer, that his Ratiocinations ſeem to me far ſhort of that cogency, which the noiſe he would make in

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the world, and the way wherein he treats both ancient and modern Philoſophers that diſſent from him, may warrant us to expect.

A. You will allow me the freedom to tell you, That, to convince me, that your reſentment of his explicating divers of the Phænomena of your Pneumatic Engine otherwiſe than you have been wont to do, (and perhaps in terms that might well have been more civil,) has had no ſhare in dictating this Judgment of yours; the beſt way will be, that entering for a while into the party of the *Vacuiſts* you anſwer the Arguments he alledges in this Chapter to confute them.

B. Having always, as you know, forborn to declare my ſelf either way in this Controverſie, I ſhall not tye my ſelf ſtrictly to the Principles and Notions of the *Vacuiſts*, nor, though but for a while, oppoſe my ſelf to thoſe of the *Pleniſts:* But ſo far I ſhall comply with your Commands, as either upon the Doctrine of the *Vacuiſts*, or upon other grounds, to conſider, *whe-*

ther this Dialogue of Mr. *Hobbes* have cogently proved his, and the Schools, Assertion, *Non dari Vacuum*; and *whether* he has rightly explain'd some Phænomena of Nature which he undertakes to give an account of, and especially some produced in our Engin, whereof he takes upon him to render the genuine Causes. And this last inquiry is that which I chiefly design.

A. By this I perceive, that if you can make out your own Explications of your Adversaries Problems *de Vacuo*, and shew them to be preferable to his, you will think you have done your work, and that 'tis but your secondary scope to shew, that in Mr. *Hobbes* his way of solving them, he gives the *Vacuists* an advantage against *Him*, though not against the *Pleniists* in general.

B. You do not mistake my meaning, and therefore without any further Preamble, let us now proceed to the particular Phænomena consider'd by Mr. *Hobbes*; the first of which is an Experiment proposed by me in the one

one and thirtieth of the *Physico-Mechanical Experiments* concerning the Adhesion of two flat and polish'd Marbles, which I endeavour'd to solve by the pressure of the Air. And this Experiment Mr. *Hobbes* thinks so convincing an one to prove the Plenitude of the World, that, though he tells us he has many cogent Arguments to make it out, yet he mentions but this one, because that, *he says*, suffices.

A. The Confidence he thereby expresses of the great force of this Argument does the less move me, because, I remember, that formerly in his *Elements of Philosophy* he thought it sufficient to employ one Argument to evince the Plenitude of the World, and for that one he pitch'd upon the Vulgar Experiment of a Gardeners Watering-Pot: But, whether he were wrought upon by the Objections made to his Inference from that Phænomenon in your Examen of his Dialogue *De Natura Aeris*, or by some other Considerations, I will not pretend to divine. But I plainly perceive, he

now prefers the Experiment of the cohering Marbles.

B. Of which it will not be amiſs, though the paſſage be ſomewhat long, to read you his whole Diſcourſe out of the Book I have in my hand.

A. 'Tis fit that you, who for my ſake are content to take the pains of anſwering what he ſays, ſhould be eaſed of the trouble of reading it, which I will therefore, with your leave, take upon me. His Diſcourſe then about the Marbles is this:

A. *Ad probandam Univerſi Plenitudinem, nullum noſtin' Argumentum cogens?*

B. *Imò multa: Unum autem ſufficit ex eo ſumptum, Quod duo corpora plana, ſi ſe mutuò ſecundùm amborum planitiem communem tangant, non facile in inſtante divelli poſſunt; ſucceſſivè verò facillimè. Non dico, impoſſibile eſſe duo duriſſima Marmora ita cohærentia divellere, ſed difficile; & vim poſtulare tantam, quanta ſufficit ad duritiem lapidis ſuperandam. Siquidem verò majore vi ad ſeparationem opus ſit quàm illa, quâ moven-*

moventur ſeparata, id ſignum eſt non dari Vacuum.

A. Aſſertiones illæ demonſtratione indigent. Primò autem oſtende, quomodo ex duorum duriſſimorum corporum, conjunctorum ad ſuperficies exquiſite læves, diremptione difficili, ſequatur Plenitudo Mundi?

B. Si duo plana, dura, polita Corpora (ut Marmora) collocentur unum ſupra alterum, ita ut eorum ſuperficies ſe mutuò per omnia puncta exactè, quantum fieri poteſt, contingant, illa ſine magna difficultate ita divelli non poſſunt, ut eodem inſtante per omnia puncta dirimantur. Veruntamen Marmora eadem, ſi communis eorum ſuperficies ad Horizontem erigatur, aut non valde inclinetur, alterum ab altero facillimè (ut ſcis) etiam ſolo pondere dilabentur. Nonne cauſa hujus rei hæc eſt, Quod labenti Marmori ſuccedit Aer, & relictum locum ſemper implet?

A. Certiſſimè. Quid ergo?

B. Quando verò eadem uno inſtante divellere conaris, nonne multo major vis adhibenda eſt; Quam ob cauſam?

A. Ego,

A. *Ego, & mecum (puto) omnes cauſam ſtatuunt, Quod ſpatium totum inter duo illa Marmora divulſa, ſimul uno inſtante implere Aer non poteſt, quantacunque celeritate fiat divulſio.*

B. *An qui ſpatia in Aere dari vacua contendunt, in illo Aere ſolo dari negant qui Marmora illa conjuncta circumdat?*

A. *Minimè, ſed ubique interſperſa.*

B. *Dum ergo illi, qui Marmor unum ab altero revellentes Aerem comprimunt, & per conſequens Vacuum exprimunt, Vacuum faciunt locum per revulſionem relictum; nulla ergo ſeparationis erit difficultas, ſaltem non major quàm eſt difficultas corpora eadem movendi in Aere poſtquam ſeparata fuerint. Itaque quoniam, conceſſo Vacuo, difficultas Marmora illa dirimendi nulla eſt, ſequitur per difficultatis experientiam, nullum eſſe Vacuum.*

A. *Recte quidem illud infers. Mundi autem Plenitudine ſuppoſita, quomodo demonſtrabis poſſibile omnino eſſe ut divellantur?*

B. *Cogita primo Corpus aliquod ductile,*

ctile, nec nimis durum, ut ceram, in duas partes distrahi, quæ tamen partes non minus exactè in communi plano se mutuo tangunt quàm lævissima Marmora. Jam quo pacto distrahatur cera, consideremus. Nonne perpetuo attenuatur donec in filum evadat tenuissimum, & omni dato crasso tenuius, & sic tandem divellitur? Eodem modo etiam durissima columna in duas partes distrahetur, si vim tantam adhibeas, quanta sufficit ad resistentiam duritiei superandam. Sicut enim in cera partes primò extimæ distrahuntur, in quarum locum succedit Aer; ita etiam in Corpore quantumlibet duro Aer locum subit partium extimarum, quæ primæ Vulsionis viribus dirumpuntur. Vis autem quæ superat resistentiam partium extimarum Duri, facilè superabit resistentiam reliquarum. Nam resistentia prima est à Toto Duro, reliquarum verò semper à Residuo.

A. *Ita quidem videtur consideranti, quàm Corpora quædam, præsertim verò durissima, fragilia sint.*

Does this Ratiocination seem to you as cogent, as it did to the Proposer of it?

B. You

E. You will quickly think it does not, and perhaps you will think it ſhould not, if you pleaſe to conſider with me ſome of the Reflections that the Reading of it ſuggeſted to me.

And firſt, without declaring for the *Vacuiſts* Opinion, I muſt profeſs my ſelf unſatisfied with Mr. *Hobbes*'s way of arguing againſt them: For, where he ſays, *Dum ergo illi qui Marmor unum ab altero revellentes Aerem comprimunt & per conſequens Vacuum exprimunt, Vacuum faciunt locum per revulſionem relictum; nulla ergo ſeparationis erit difficultas, ſaltem non major quàm eſt difficultas corpora eadem movendi in Aere poſtquam ſeparata fuerint. Itaque quoniam, conceſſo Vacuo, difficultas Marmora illa dirimendi nulla eſt, ſequitur per difficultatis experientiam, nullum eſſe Vacuum.* Methinks he expreſſes himſelf but obſcurely, and leaves his Readers to gheſs, what the word *Dum* refers to. But that which ſeems to be his drift in this paſſage, is, that, ſince the *Vacuiſts* allow interſperſed Vacuities, not only in the Air

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that ſurrounds the conjoyned Marbles, but in the reſt of the ambient Air, there is no reaſon, why there ſhould be any difficulty in ſeparating the Marbles, or at leaſt any greater difficulty than in moving the Marbles in that Air after their ſeparation. But, not to conſider, whether his Adverſaries will not accuſe his phraſe of *ſqueezing out a Vacuum* as if it were a Body, they will eaſily anſwer, that notwithſtanding the Vacuities they admit in the ambient Air, a manifeſt reaſon may be given in their Hypotheſis of our finding a difficulty in the Divulſion of the Marbles. For, the Vacuities they admit being but interſpers'd, and very ſmall, and the Corpuſcles of the Atmoſphere being according to them endow'd with Gravity, there leans ſo many upon the upper ſurface of the uppermoſt Marble, that that ſtone cannot be at once perpendicularly drawn up from the lower Marble contiguous to it, without a force capable to ſurmount the weight of the Aerial Corpuſcles

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that lean upon it. And this weight has already ſo conſtipated the neighbouring parts of the ambient Air, that he, that would perpendicularly raiſe the upper Marble from the lower, ſhall need a conſiderable force to make the Revulſion, and compel the already contiguous parts of the incumbent Air to a ſubingreſſion into the pores or intervals intercepted between them. For the *Conatus* of him, that endeavours to remove the upper Marble, whilſt the lower ſurface of it is fenc'd from the preſſure of the Atmoſphere by the Contact of the lower Marble which ſuffers no Air to come in between them, is not aſſiſted by the weight or preſſure of the Atmoſphere, which, when the Marbles are once ſeparated, preſſing as ſtrongly againſt the undermoſt ſurface of the upper Marble, as the incumbent Atmoſpherical Pillar does againſt the upper ſurface of the ſame Marble, the hand that endeavours to raiſe it in the free Air has no other reſiſtance, than that ſmall one of the Marbles own weight to ſurmount. *A.* But

A. But what ſay you to the Reaſon that Mr. *Hobbes*, and, as he thinks, all others give of the difficulty of the often mention'd Divulſion, namely, *Quòd ſpatium totum inter duo illa Marmora divulſa ſimul uno inſtante implere Aer non poteſt, quantacunque celeritate fiat divulſio.*

B. I ſay, that, for ought I know, the Pleniſts may give a more plauſible account of this Experiment, than Mr. *Hobbes* has here done; and therefore abſtracting from the two oppoſite Hypotheſes, I ſhall further ſay, That the genuine Cauſe of the Phænomenon ſeems to be that which I have already aſſign'd; and that difficulty of raiſing the upper ſtone that accompanies the Airs not being able to come in all at once, to poſſeſs the ſpace left between the ſurfaces of the two Marbles upon their ſeparation, proceeds from hence, that, 'till that ſpace be fill'd with the Atmoſpherical Air, the hand of him that would lift up the ſuperiour Marble cannot be fully aſſiſted by the preſſure of the

the Air againſt the lower ſurface of that Marble.

A. This is a Paradox, and therefore I ſhall deſire to know on what you ground it?

B. Though I mention it but as a Conjecture propos'd *ex abundanti*, yet I ſhall on this occaſion countenance it with two things; the *firſt*, that, ſince I declare not for the Hypotheſis of the *Pleniſts* as 'tis maintain'd by Mr. *Hobbes*, I am not bound to allow, what the common Explication, adopted by my Adverſary, ſuppoſes; namely, that either Nature abhors a *Vacuum* (as the Schools would have it,) or that there could be no Divulſion of the Marbles, unleſs at the ſame time the Air were admitted into the room that Divulſion makes for it. And a *Vacuiſt* may tell you, that, provided the ſtrength employ'd to draw up the ſuperiour Marble be great enough to ſurmount the weight of the Aerial Corpuſcles accumulated upon it, the divulſion would enſue, though by Divine Omnipotence no

Air

Air or other Body ſhould be permitted to fill the room made for it by the divulſion; and that the Air's ruſhing into that ſpace does not neceſſarily accompany, but in order of Nature and time follow upon, a ſeparation of the Marbles, the Air that ſurrounded their contiguous ſurfaces being by the weight of the collaterally ſuperiour Air impell'd into the room newly made by the divulſion. But I ſhall rather countenance what you call my Paradox by an Experiment I purpoſely made in our Pneumatical Receiver, where having accommodated two flat and poliſh'd Marbles, ſo that the lower being fixt, the upper might be laid upon it and drawn up again as there ſhould be occaſion, I found, that if, when the Receiver was well exhauſted, the upper Marble was by a certain contrivance laid flat upon the lower, they would not then cohere as formerly, but be with great eaſe ſeparated, though it did not by any Phænomenon appear, that any Air could

come to ruſh in, to poſſeſs the place given it by the receſs of the upper Marble, whoſe very eaſie avulſion is as eaſily explicable by our Hypotheſis; ſince the preſſure of that little Air, that remain'd in the Receiver, being too faint to make any at all conſiderable reſiſtance to the avulſion of the upper Marble, the hand that drew it up had very little more than the ſingle weight of the ſtone to ſurmount.

A. An *Anti-pleniſt* had expected, that you would have obſerved, that the difficult ſeparation of the Marbles in the open Air does rather prove, that there may be a *Vacuum*, than that there can be none. For in caſe the Air can ſucceed as faſt at the ſides as the divulſion is made, a *Vacuiſt* may demand, whence comes the difficulty of the ſeparation? And if the Air cannot fill the whole room made for it by the ſeparated Marbles at the ſame inſtant they are forc'd aſunder, how is a *Vacuum* avoided for that time, how ſmall ſoever, that is neceſſary

ceſſary for the Air to paſs from the edges to the middle of the room newly made?

B. What the *Pleniſts* will ſay to your Argument I leave them to conſider; but I preſume, they will be able to give a more plauſible account of the Phænomenon we are treating of, than is given by Mr. *Hobbes.*

A. What induces you to diſlike his Explication of it?

B. Two things; the one, that I think the Cauſe he aſſigns improbable; and the other, that I think another, that is better, has been aſſign'd already.

And *firſt*, whereas Mr. *Hobbes* requires to the Divulſion of the Marbles a force great enough to ſurmount the hardneſs of the ſtone, this is aſſerted *gratis*, which it ſhould not be; ſince it ſeems very unlikely, that the weight of ſo few pounds as will ſuffice to ſeparate two coherent Marbles of about an Inch, for inſtance, in Diameter, ſhould be able to ſurmount the hardneſs of ſuch ſolid

ſtones as we uſually employ in this Experiment. And though it be generally judg'd more eaſie to bend, if it may be, or break a broader piece of Marble *cæteris paribus*, than a much narrower; yet, whereas neither I, nor any elſe that I know, nor I believe Mr. *Hobbes*, ever obſerv'd any difference in the reſiſtance of Marbles to ſeparation from the greater or leſſer thickneſs of the ſtones; I find by conſtant experience, that, *cæteris paribus*, the broadneſs of the coherent Marbles does *exceedingly* increaſe the difficulty of disjoyning them: Inſomuch that, whereas not many pounds, as I was ſaying, would ſeparate Marbles of an Inch, or a leſſer, Diameter; when I increaſed their Diameter to about four Inches, if I miſremember not, there were ſeveral Men that ſucceſſively try'd to pull them aſunder without being able by their utmoſt force to effect it.

A. But what ſay you to the Illuſtration, that Mr. *Hobbes*, upon the ſuppoſition of the Worlds Plenitude, gives

gives of our Phænomenon by drawing aſunder the oppoſite parts of a piece of Wax?

B. To me it ſeems an Inſtance improper enough. For *firſt*, the parts that are to be divided in the Wax are of a ſoft and yielding conſiſtence, and according to him of a ductile, or, if you pleaſe, of a tractile nature, and not, as the parts of the coherent Marbles, very ſolid and hard. *Next*, the parts of the Wax do not ſtick together barely by a ſuperficial contact of two ſmooth Planes, as do the Marbles we are ſpeaking of; but have their parts implicated, and as it were intangled with one another. And therefore they are far from a diſpoſition to ſlide off, like the Marbles, from one another, in how commodious a poſture ſoever you place them. Beſides 'tis manifeſt, that the Air has opportunity to ſucceed in the places ſucceſſively deſerted by the receding parts of the attenuated Wax; but 'tis neither manifeſt, nor as yet well proved by Mr. *Hobbes*, that the

Air does after the ſame manner ſucceed between the two Marbles, which, as I lately noted, are not forced aſunder after ſuch a way, but are, as himſelf ſpeaks, ſever'd in all their points at the ſame inſtant.

A. I know, you forget not what he ſays of the dividing of a hard Column into two parts by a force ſufficient to overcome the reſiſtance of its hardneſs.

B. He does not here either affirm, that he, or any he can truſt, has ſeen the thing done; nor does he give us any ſuch account of the way wherein the Pillar is to be broken, whether in an erected, inclined, or horizontal poſture; nor deſcribe the particular circumſtances that were fit to be mention'd in order to the ſolution of the Phænomenon. Wherefore, 'till I be better inform'd of the matter of fact, I can ſcarce look upon what Mr. *Hobbes* ſays of the Pillar, as other than his Conjecture, which now I ſhall the rather paſs by, not only becauſe the caſe is differing

fering from that of our poliſh'd Marbles, which are actually diſtinct Bodies, and only contiguous in one Commiſſure; but alſo, becauſe I would haſten to the *ſecond* reaſon of my diſlike of Mr. *Hobbes*'s Explication of our Phænomenon, which is, that a better has been given already, from the preſſure of the Atmoſphere upon all the ſuperficial parts of the upper Marble ſave thoſe that touch the Plane of the lower.

A. You would have put fair for convincing Mr. *Hobbes* himſelf, at leaſt would have put him to unuſual ſhifts, if you had ſucceeded in the attempt you made, among other of your Phyſico-Mechanical Experiments, to disjoyn two coherent Marbles, by ſuſpending them horizontally in your Pneumatical Receiver, and pumping out the Air that inviron'd them; for, from your failing in that attempt, though you rendred a not improbable Reaſon of it, Mr. *Hobbes* took occaſion, in his Dialogue *De Natura Aeris*, to ſpeak in

ſo high a ſtrain as this: *Nihil iſthic erat quod ageret pondus; Experimento hoc excogitari contra opinionem eorum qui Vacuum aſſerunt aliud argumentum fortius aut evidentius non potuit. Nam ſi duorum cohærentium alterutrum ſecundùm eam viam, in qua jacent ipſæ contiguæ ſuperficies, propulſum eſſet, facile ſeparārentur, Aere praximo in locum relictum ſucceſſivè ſemper influente; ſed illa ita divellere, ut ſimul totum amitterent contactum, impoſſibile eſt, mundo pleno. Oporteret enim aut motum fieri ab uno termino ad alium in inſtante, aut duo corpora eodem tempore in eodem eſſe loco: Quorum utrumvis dicere, eſt abſurdum.*

B. You may remember, that where I relate that Experiment, I expreſs'd a hope, that, when I ſhould be better accommodated than I then was, I might attempt the Tryal with proſperous ſucceſs, and accordingly afterwards, having got a leſſer Engine than that I uſed before, wherewith the Air might be better pumpt out and longer kept out, I cheerfully repeated the Tryal. To ſhew then,

that

that when two coherent Marbles are ſuſtained horizontally in the Air, the Cauſe, why they are not to be forc'd aſunder, if they have two or three Inches in Diameter, without the help of a conſiderable weight, is the preſſure I was lately mentioning of the ambient Air; I cauſed two ſuch coherent Marbles to be ſuſpended in a large Receiver, with a weight at the lowermoſt, that might help to keep them ſteddy, but was very inconſiderable to that which their Coheſion might have ſurmounted; then cauſing the Air to be pumpt by degrees out of the Receiver, for a good while the Marbles ſtuck cloſe together, becauſe during that time the Air could not be ſo far pumpt out, but that there remained enough to ſuſtain the ſmall weight that endeavoured their divulſion: But when the Air was further pumpt out, at length the Spring of the little, but not a little expanded, Air, that remained, being grown too weak to ſuſtain the lower Marble

and

and its ſmall clog, they did, as I expected, drop off.

A. This will not agree over-well with the confident and triumphant expreſſions juſt now recited.

B. I never envied Mr. *Hobbes*'s forwardneſs to triumph, and am content, his Conjectures be recommended by the confidence that accompanies them, if mine be by the ſucceſs that follows them. But to confirm the Explication given by me of our Phænomenon, I ſhall add, that as the laſt mention'd Tryal, which I had ſeveral times occaſion to repeat, ſhews, that the coheſion of our two contiguous Marbles would ceaſe upon the withdrawing of the preſſure of the Atmoſphere; ſo by another Experiment I made, it appears, that the ſupervening of that preſſure ſufficed to cauſe that Coheſion. For, in proſecution of one of the lately mentioned Tryals, having found, that when the Receiver was well exhauſted, two Marbles, though conſiderably broad, being laid upon one

ano-

another after the requiſite manner, their adheſion was, if any at all, ſo weak, that the uppermoſt would be eaſily drawn up from off the other; we laid them again one upon the other, and then letting the external Air flow into the Receiver, we found, according to expectation, that the Marbles now cohered well, and we could not raiſe the uppermoſt but accompanied with the lowermoſt. But I am ſenſible, I have detained you too long upon the ſingle Experiment of the Marbles: And though I hope the ſtreſs Mr. *Hobbes* lays on it will plead my excuſe, yet to make your Patience ſome amends, I ſhall be the more brief in the other particulars that remain to be conſider'd in his Dialogue *De Vacuo.* And 'twill not be difficult for me to keep my promiſe without injuring my Cauſe, ſince almoſt all theſe particulars being but the ſame which he has already alledged in his Dialogue *De Naturâ Aeris*, and I ſoon after anſwered in my *Examen* of that Dialogue,

logue, I ſhall need but to refer you to the paſſages where you may find theſe Allegations examin'd, only ſubjoyning here ſome Reflections upon thoſe few and ſlight things, that he has added in his Problems *De Vacuo*.

A. I may then, I ſuppoſe, read to you the next paſſage to that long one, you have hitherto been conſidering, and it is this: *Ad Vacuum nunc revertor: Quas cauſas ſine ſuppoſitione Vacui redditurus es illorum effectuum, qui oſtenduntur per Machinam illam quæ eſt in Collegio* Greſhamenſi?

B. *Machina illa* —

B. Stop here, I beſeech you, a little, that, before we go any further, I may take notice to you of a couple of things that will concern our ſubſequent Diſcourſe.

Whereof the *firſt* is, that it appears by Mr. *Hobbes's Dialogue about the Air*, that the Explications he there gave of ſome of the Phænomena of the *Machina Boyliana*, were directed partly againſt the *Virtuoſi*, that have ſince been honour'd with the Title of

of the *Royal Society*, and partly againſt the Author of that Engine, as if the main thing therein deſign'd were to prove a *Vacuum*. And ſince he now repeats the ſame explications, I think it neceſſary to ſay again, that if he either takes the *Society* or me for profeſs'd *Vacuiſts*, he miſtakes, and ſhoots beſide the mark; for, neither they nor I have ever yet declar'd either *for* or *againſt* a *Vacuum*.

And the *other* thing I would obſerve to you, is, that Mr. *Hobbes* ſeems not to have rightly underſtood, or at leaſt not to have ſufficiently heeded in what chiefly conſiſts the advantage, which the *Vacuiſts* may make of our Engine againſt him: For, whereas in divers places he is very ſolicitous to prove, that the cavity of our Pneumatical Receiver is not altogether empty, the Vacuiſts may tell him, that ſince he aſſerts the *abſolute* plenitude of the World, he muſt, as indeed he does, reject not only great Vacuities, but alſo thoſe very ſmall and interſpers'd ones,

ones, that they ſuppoſe to be intercepted between the ſolid corpuſcles of other bodies, particularly of the Air: So that it would not confute them to prove, that in our Receiver, when moſt diligently exhauſted, there is not one great and abſolute Vacuity, or, as they ſpeak, a *Vacuum coacervatum*, ſince ſmaller and diſſeminated Vacuities would ſerve their turn. And therefore they may think their Pretenſions highly favour'd, as by ſeveral particular effects, ſo by this general Phænomenon of our Engine, that it appears by ſeveral Circumſtances, that the Common or Atmoſpherical Air, which, before the pump is ſet a work, poſſeſs'd the whole cavity of our Receiver, far the greateſt part is by the intervention of the pump made to paſs out of the cavity into the open Air, without being able, at leaſt for a little while, to get in again; and yet it does not appear by any thing alledg'd by Mr. *Hobbes*, that any other body ſucceeds to fill adequately the

the places deſerted by ſuch a multitude of Aerial corpuſcles.

A. If I gheſs aright, by thoſe words, (viz. *it appears not by any thing alledg'd by Mr.* Hobbes,) you deſign to intimate, that you would not in general prejudice the Pleniſts.

B. Your conjecture was well founded: For I think divers of them, and particularly the *Carteſians*, who ſuppoſe a ſubtile Matter or *Æther* fine enough to permeate glaſs, though our common Air cannot do it, have not near ſo difficult a task to avoid the Arguments the Vacuiſts may draw from our Engine, as Mr. *Hobbes*, who, without having recourſe to the poroſity of glaſs, which indeed is impervious to *common* Air, ſtrives to ſolve the Phænomena, and prove our Receiver to be always perfectly full, and therefore as full at any one time as at any other of common or Atmoſpherical Air, as far as we can judge of his opinion by the tendency or import of his Explications.

A. Yet, if I were rightly inform'd of

of an Experiment of yours, Mr. *Hobbes* may be thereby reduc'd either to paſs over to the *Vacuiſts*, or to acknowledge ſome Ætherial or other matter more ſubtil than Air, and capable of paſſing through the pores of glaſs; and therefore, to ſhew your ſelf impartial between the Vacuiſts and their Adverſaries in this Controverſie, I hope you will not refuſe to gratifie the *Pleniſts* by giving your friends a more particular account of the Experiment.

B. I know which you mean, and remember it very well. For, though I long ſince devis'd it, yet having but the other day had occaſion to peruſe the Relation I writ down of one of the beſt Tryals, I think I can repeat it, almoſt in the very words, which, if I miſtake not, were theſe:

There was taken a Bubble of thin white glaſs, about the bigneſs of a Nutmeg, with a very ſlender ſtem, of about four or five Inches long, and of the bigneſs of a Crows-quill.

The

The end of the Quill being held in the flame of a Lamp blown with a pair of Bellows, was readily and well ſeal'd up, and preſently the globous part of the glaſs, being held by the ſtem, was kept turning in the flame, 'till it was red hot and ready to melt; then being a little removed from the flame, as the included Air began to loſe of its agitation and ſpring, the external Air manifeſtly and conſiderably preſs'd in one of the ſides of the Bubble. But the glaſs being again, before the cold could crack it, held as before in the flame, the rarified Air diſtended and plump'd up the Bubble; which being the ſecond time remov'd from the flame, was the ſecond time compreſs'd; and, being the third time brought back to the flame, ſwell'd as before, and remov'd, was again compreſs'd, (either this time or the laſt by two diſtinct cavities;) 'till at length, having ſatisfied our ſelves, that the included Air was capable of being condens'd or dilated without the ingreſs or

egreſs of Air (properly ſo called) we held the Bubble ſo long in the flame, ſtrengthen'd by nimble blaſts, that not only it had its ſides plump'd up, but a hole violently broken in it by the over-rarified Air, which, together with the former watchfulneſs, we imploy'd from time to time to diſcern if it were any where crackt or perforated, ſatisfied us that it was till then intire.

A. I confeſs, I did not readily conceive before, how you could, (as I was told you had,) make a ſolid Veſſel, wherein there was no danger of the Aires getting in or out, whoſe cavity ſhould be ſtill poſſeſt with the ſame Air, and yet the Veſſel be made by turns bigger and leſſer. And, though I preſently thought upon a well ſtopt bladder, yet I well foreſaw, that a diſtruſtful Adverſary might make ſome Objections, which are by your way of proceeding obviated, and the Experiment agrees with your Doctrine in ſhewing, how impervious we may well think your thick

Pneu-

Pneumatick Receivers are to common Air, ſince a thin glaſs Bubble, when its pores were open'd or relax'd by flame, would not give paſſage to the Springy particles of the Air, though violently agitated; for if thoſe particles could have got out of the pores, they never would have broke the Bubble, as at length a more violent degree of Heat made them do; nor probably would the Compreſſion, that afterwards inſued of the Bubble by the ambient Air, be checkt near ſo ſoon, if thoſe Springy Corpuſcles had not remained within to make the reſiſtance. Methinks, one may hence draw a new proof of what I remember you elſewhere teach, that the Spring of the Air may be much ſtrengthen'd by Heat. For, in our caſe, the Spring of the Air was thereby inabled to expand the compreſt glaſs, it was impriſon'd in, in ſpite of the reſiſting preſſure of the external Air; and yet, that this preſſure was conſiderable, appears by this, that the weight of ſo ſmall a Column

of Atmoſpherical Air, as could bear upon the Bubble, was able to preſs in the heated glaſs, in ſpite of the reſiſtance of its tenacity and arched figure.

B. Yet that which I mainly deſign'd in this Experiment was, (if I were able) to ſhew and prove at once, by an Inſtance not lyable to the ordinary exceptions, the true Nature of Rarefaction and Condenſation, at leaſt of the Air. For, to ſay nothing of the *Peripatetick* Rarefaction and Condenſation, ſtrictly ſo call'd, which I ſcruple not to declare, I think to be phyſically inconceptible or impoſſible; 'tis plain by our Experiment, that, when the Bubble, after the Glaſs had been firſt thruſt in towards the Center, was expanded again by heat, the included Air *poſſeſs'd* more room than before, and yet it could perfectly *fill* no more room than formerly, each Aerial Particle taking up, both before and after the heating of the Bubble, a portion of ſpace adequate to its own bulk; ſo that in the Cavity of the expan-

expanded Bubble we muſt admit either Vacuities interſpers'd between the Corpuſcles of the Air, or that ſome fine Particles of the Flame, or other ſubtil matter, came in to fill up thoſe Intervals, which matter muſt have enter'd the Cavity of the Glaſs at its pores: And afterwards, when the red-hot Bubble was removed from the flame, it is evident, that, ſince the groſſer particles of the Air could not get through the Glaſs, which they were not able to do, even when vehemently agitated by an ambient Flame, the Compreſſion of the Bubble, and the Condenſation of the Air, which was neceſſarily conſequent upon it, could not, ſuppoſing the Plenitude of the World, be performed without ſqueezing out ſome of the ſubtil matter contained in the cavity of the Bubble, whence it could not iſſue but at the pores of the Glaſs. But I will no longer detain you from Mr. *Hobbes* his Explications of the *Machina Boyliana*; to the firſt of which you may now, if you pleaſe, advance.

A. The passage I was going to read, when you interrupted me, was this:

B. *Machina illa eosdem effectus producit, quos produceret in loco non magno magnus inclusus ventus.*

A. *Quomodo ingreditur istuc ventus? Machinam nosti Cylindrum esse cavum, æneum, in quem protruditur Cylindrus alius solidus ligneus, corio tectus, (quem suctorem dicunt) ita exquisitè congruens, ut ne minimus quidem Aer inter corium & æs intrare (ut putant) possit.*

B. *Scio, & quò Suctor facilius intrudi possit, foramen quoddam est in superiori parte Cylindri, per quod Aer (qui suctoris ingressum alioqui impedire possit) emittatur. Quod foramen aperire possunt & claudere quoties usus postulat. Est etiam in Cylindri cavi recessu summo datus aditus Aeri in globum concavum Vitreum, quem etiam aditum claviculâ obturare & aperire possunt quoties volunt. Denique in globo vitreo summo relinquitur foramen satis amplum, (claviculâ item claudendum & recludendum) ut in illum quæ volunt immittere possint, experiendi causâ.*

B. The

B. The imaginary wind to which Mr. *Hobbes* here aſcribes the effects of our Engine, he formerly had recourſe to in the 13th page of his *Dialogue*, and I have ſufficiently anſwer'd that paſſage of it in the 45th and 46th pages of my *Examen*, to which I therefore refer you.

A. I preſume, you did not overlook the compariſon Mr. *Hobbes* annexes to what I laſt read out of his Problems, ſince he liked the conceit ſo well, that we meet with it in this place again, though he had formerly printed it in his Dialogue *De Natura Aeris.* The words (as you ſee) are theſe: *Tota denique Machina non multum differt, ſi naturam ejus ſpectes, à Sclopeto ex Sambuco, quo pueri ſe delectant, imitantes Sclopetos militum, niſi quòd major ſit, & majori arte fabricatus, & pluris conſtet.*

B. I could ſcarce, for the reaſon you give, avoid taking notice of it. And if Mr. *Hobbes* intended it for a piece of Ralliery, I willingly let it paſs, and could eaſily forgive him a more

conſiderable attempt than this, to be reveng'd on an Engine that has deſtroyed ſeveral of his opinions: But, if he ſeriouſly meant to make a Phyſical Compariſon, I think he made a very improper one. For, not to urge, that one may well doubt how he knows, that in the incloſed cavity of his Pot-gun, there is a very vehement wind, (ſince that does not neceſſarily follow from the compreſſion of the included Air:) In Mr. *Hobbes*'s Inſtrument, the Air, being forcibly compreſt, has an endeavour to expand it ſelf, and when it is able to ſurmount the reſiſtance of its priſon, that part that is firſt disjoyn'd is forcibly thrown outwards; whereas in our Engine it appears by the paſſage lately cited of our *Examen*, that the Air is not compreſt but expanded in our Receiver, and if an intercourſe be open'd, or the Veſſel be not ſtrong enough, the outward Air violently ruſhes in: And if the Receiver chance to break, the fragments of the glaſs are not thrown outwards, but forced inwards.

A. So

A. So that, whether or no Mr. *Hobbes* could have pitch'd upon a Compariſon more ſuitable to his Intentions, he might eaſily have imployed one more ſuitable to the *Phænomena.*

B. I preſume, you will judge it the leſs agreeable to the Phænomena, if I here ſubjoyn an Experiment, that poſſibly you will not diſlike; which I devis'd to ſhew, not only that in our exhauſted Receivers there is no ſuch ſtrong endeavour outwards, as moſt of Mr. *Hobbes*'s Explications of the things that happen in them are built upon, but that the weight of the Atmoſpherical Air, when 'tis not reſiſted by the counterpreſſure of any internal Air, is able to perform what a weight of many pounds would not ſuffice to do.

A. I ſhall the more willingly learn an Experiment to this purpoſe, becauſe in your Receivers, the rigidity of the glaſs keeps us from ſeeing, by any manifeſt change of its figure, whether, if it could yield without breaking,

breaking, it would be preſs'd in, as your Hypotheſis requires.

B. The deſires to obviate that very difficulty, for their ſatisfaction, that had not yet penetrated the grounds of our *Hypotheſis*, made me think of employing, inſtead of a Receiver of Glaſs, one of a ſtiff and tough, but yet ſomewhat flexible, Metal. And accordingly having provided a new Pewter Porrenger, and whelm'd it upſide down upon an Iron plate faſten'd to (the upper end of) our Pneumatical Pump, we carefully faſten'd by Cement the orifice to the plate, and though the inverted Veſſel, by reaſon of its ſtiffneſs and thickneſs and the convexity of its ſuperficies, were ſtrong enough to have ſupported a great weight without changing its figure; yet, as ſoon as by an exſuction or two the remaining part of the included Air was brought to ſuch a degree of expanſion, that its weaken'd Spring was able to afford but little aſſiſtance to the tenacity and firmneſs of the Metal, the

the weight of the pillar of the incumbent Atmoſphere (which by reaſon of the breadth of the Veſſel was conſiderably wide alſo) did preſently and notably depreſs the upper part of the Porringer, both leſſening its capacity and changing its figure; ſo that inſtead of the Convex ſurface, the Receiver had before, it came to a Concave one, which new figure was ſomewhat, though not much, increaſed by the further withdrawing of the included and already rarified Air. The Experiment ſucceeded alſo with an other common Porringer of the ſame Metal. But in ſuch kind of Veſſels, made purpoſely of Iron plates, it will ſometimes ſucceed and ſometimes not, according to the Diameter of the veſſel and the thickneſs of the plate, which was ſometimes ſtrong enough and ſometimes too weak to reſiſt the preſſure of the incumbent Air. And ſometimes I found alſo, that the veſſel would be thruſt in, not at the top but ſide-ways, in caſe *that* ſide were the only part that were

were made too thin to reſiſt the preſſure of the Ambient; which Phænomenon I therefore take notice of, that you may ſee, that that powerful preſſure may be exercised laterally as well as perpendicularly.

Perhaps this Experiment, and that I lately recited of an Hermetically ſealed Bubble, by their fitneſs to diſprove Mr. *Hobbes*'s Doctrine, may do ſomewhat towards the letting him ſee, that he might have ſpar'd that not over-modeſt and wary expreſſion, where ſpeaking of the Gentlemen that meet at *Greſham-College*, (of whom I pretend not to be one of the chief) he is pleaſed to ſay, *Experimenta faciant quantum volunt, niſi Principiis utantur meis nihil proficient.* But let us, if you pleaſe, paſs on to what he further alledges to prove, that the ſpace in the exhauſted Receiver, which the Vacuiſts ſuppoſe to be *partly* empty, is full of Air. (*Video* (ſays A.) *ſi ſuctor trudatur uſque ad fundum Cylindri Æneï, obturenturque foramina, Secuturum eſſe, dum ſuctor retrahitur, locum*

locum in Cylindro cavo relictum fore vacuum. Nam ut in locum ejus ſuccedat Aer, eſt impoſſibile. To which B. anſwers, *Credo equidem, ſuctorem cum Cylindri cavi ſuperficie ſatis arctè cohærere ad excludendum ſtramen & plumam, non autem Aerem neque Aquam. Cogita enim, quod non ita accuratè congruerent, quin undiquaque interſtitium relinqueretur, quantum tenuiſſimi capilli capax eſſet. Retracto ergo ſuctore, tantum impelleretur Aeris, quantum viribus illis conveniret quibus Aer propter ſuctoris Retractionem reprimitur, idque ſine omni difficultate ſenſibili. Quanto autem interſtitium illud minus eſſet, tantum ingrederetur Aer velocius: Vel ſi contactus ſit, ſed non per omnia puncta, etiam tunc intrabit Aer, modò ſuctor majore vi retrahatur. Poſtremò, etſi contactus ubique exactiſſimus ſit, vi tamen ſatis auctâ per cochleam ferream, tum corium cedet, tum ipſum es; atque ita quoque ingredietur Aer. Credin' tu, poſſibile eſſe duas ſuperficies ita exactè componere, ut has compoſitas eſſe ſupponunt illi; aut corium ita durum eſſe,*

ut

ut Aeri, qui Cochleæ ope incutitur, nihil omnino cedat? Corium quanquam optimum admittit aquam, ut ipse scis, si fortè fecisti unquam iter vento & pluvia ὑόμενος καὶ ἀήμενος. *Itaque dubitare non potes, quin retractus Suctor tantum Aeris in Cylindrum adeoque in ipsum Recipiens incutiat, quantum sufficit ad locum semper relictum* perfectè *implendum. Effectus ergo, qui oritur à Retractione suctoris, alius non est quàm ventus, ventus (inquam) vehementissimus, qui ingreditur undiquaque inter Suctoris superficiem convexam, & Cylindri ænei concavam, proceditque (versâ claviculâ) in cavitatem globi Vitrei, sive (ut vocatur) Recipientis.*

The Substance of this Ratiocination having been already propos'd by Mr. *Hobbes* in his Dialogue of the Air, the 11th page, I long since answer'd it in the 30th and some of the following pages of my *Examen*; and therefore I shall only now take notice *in transitu* of some slight whether additions or variations, that occur in what you have been reading. And, *first*,

firſt, I ſee no probability in what he *gratis* aſſerts, that ſo thick a Cylinder of Braſs, as made the chief part of the pump of our Engine, ſhould yield to the Sucker, that was mov'd up and down in it, though by the help of an Iron rack; and whereas he adds, that the leather, that ſurrounds the more ſolid part of the Sucker, would yield to ſuch a force; it ſeems, that that compreſſion of the leather ſhould by thruſting the ſolid parts into the pores make the leather rather leſs than more fit to give paſſage to the Air; nor would it however follow, notwithſtanding Mr. *Hobbes*'s Example, that, becauſe a Body admits Water, it muſt be pervious to Air: For I have ſeveral times, by ways elſewhere taught, made Water penetrate the pores of Bladders, and yet Bladders reſiſt the paſſage of the Air ſo well, that even when Air included in them was ſufficiently rarified by Heat, or by our Engine, it was neceſſary for the Air to break them before it could get out; which would

would not have been, if it could have eſcap'd through their pores. What Mr. *Hobbes* inculcates here again concerning his *ventus vehementiſſimus*, you will find anſwer'd in the place of my *Examen* I lately directed you to.

A. We may then proceed to Mr. *Hobbes*'s next Explication, which he propoſes in theſe terms:

A. *Cauſam video nunc unius ex Machinæ mirabilibus, nimirum cur Suctor, poſtquam eſt aliquatenus retractus & deinde amiſſus, ſubitò recurrit ad Cylindri ſummitatem. Nam Aer, qui vi magna fuit impulſus, rurſus per repercuſſionem ad externa vi eadem revertitur.*

B. *Atque hoc quidem Argumenti ſatis eſt etiam ſolum, quòd locus à ſuctore relictus non eſt Vacuus. Quid enim aut attrahere aut impellere ſuctorem potuit ad locum illum unde retractus erat, ſi Cylindrus fuiſſet vacuus? Nam ut Aeris pondus aliquod id efficere potuiſſet, falſum eſſe ſatis ſupra demonſtravi ab eo quod Aer in Aere gravitare non poteſt. Noſti etiam, quod cum è recipiente*

Aerem

Aerem omnem (ut illi loquuntur) exegerint, poſſunt tamen trans vitrum id quod intus ſit videre, & ſonum, ſi quis fiat, inde audire. Id quod ſolum, etſi nullum aliud Argumentum eſſet (ſunt autem multa,) ad probandum, nullum *eſſe in Recipiente Vacuum, abundè ſufficit.*

B. Here are ſeveral things joyn'd together, which the Author had before ſeparately alledg'd in his oftenmention'd Dialogue. The *firſt* is, the Cauſe he aſſigns of the aſcenſion of the Sucker forcibly depreſt to the bottom of the exhauſted Cylinder, and then let alone by him that pumpt; to which might be added, that this aſcenſion ſucceeded, when the Sucker was clogg'd with an hundred pound weight. This Explication of Mr. *Hobbes* you will find examin'd in the 33th and 39th, and ſome enſuing pages of my Diſcourſe. And as to his denying, that the weight or preſſure of the Air could drive up the Sucker in that Phænomenon, becauſe the Air does not weigh in Air, we may ſee the contrary largely proved in divers

places of my *Examen*, and more particularly and expreſly in the four firſt pages of the *third* Chapter. And whereas he ſays in the laſt place, that the viſibility of Bodies included in our Receivers, and the propagation of Sound, (which, by the way, is not to be underſtood of all Sound that may be heard, though made in the exhauſted Receiver,) are alone ſufficient Arguments to prove no *Vacuum*: I have conſider'd that paſſage in the anſwer I made to the like allegation in the 45th page of the *Examen*; and ſhall only obſerve here, that, ſince the *Vacuiſts* can prove, that much of the Air is pumpt out of the exhauſted Receiver, and will pretend, that, notwithſtanding many interſpers'd Vacuities, there may be in the Receiver corporeal ſubſtance enough to tranſmit Light and ſtronger Sounds, Mr. *Hobbes* has not perform'd what he pretended, if he have but barely proved, that there may be Subſtances capable of conveying Light and Sound in the cavity of our Re-

Receiver, ſince he triumphantly aſſerts, *Nullum eſſe in Recipienti Vacuum.* But we may leave Mr. *Hobbes* and his Adverſaries to diſpute out this point, and go on to the next paſſage.

A. Which follows in theſe words: *Ad illud autem, quod ſi Veſica aliquatenus inflata in Recipiente includatur, paulo poſt per exuctionem aeris inflatur vehementiùs & dirumpitur, quid reſpondes?*

B. *Motus partium Aeris undiquaque concurrentium velociſſimus & per concurſum in ſpatiis breviſſimis numeroque infinitis gyrationis velociſſimæ veſicam in locis innumerabilibus ſimul & vi magna, inſtar totidem terebrarum, penetrat, præſertim ſi veſica, antequam immittatur, quò magis reſiſtat aliquatenus inflata ſit. Poſtquam autem Aer penetrans ſemel ingreſſus eſt, facile cogitare potes, quo pacto deinceps veſicam tendet, & tandem rumpet. Verùm ſi antequam rumpatur, verſâ claviculâ, Aer externus admittatur, videbis veſicam propter vehementiam motus temperatam diminutâ tenſione rugoſiorem. Nam id quoque obſervatum eſt. Jam ſi hæc, quam dixi,*

cauſa minùs tibi videatur veriſimilis, vide an tu aut alius quicunque imaginari poteſt, quo pacto veſica diſtendi & rumpi poſſit à viribus Vacui, id eſt, Nihili.

B. This Explication Mr. *Hobbes* gave us in the 19th page of his Dialogue *De Natura Aeris*, and you may find it at large confuted in the latter part of the third Chapter of my *Examen*. Nor does, what he here ſays in the cloſe about the *Vires Vacui* or *Nihili*, deſerve to detain us, ſince there is no reaſon at all, that the *Vacuiſts* ſhould aſcribe to *nothing* a power of breaking a Bladder, of whoſe rupture the Spring of the included Air ſupplies them ſo eaſily with a ſufficient Cauſe.

After what Mr. *Hobbes* has ſaid of the breaking of a Bladder, he proceeds to an Experiment which he judges of affinity with it, and his Academian having propos'd this Queſtion:

Unde fit ut animalia tam cito, nimirum ſpatio quatuor minutorum horæ, in recipiente interficiantur?

For

For anſwer to it our Author ſays:

B. *Nonne animalia ſic incluſa inſugunt in Pulmones Aerem vehementiſſimè motum? Quo motu neceſſe eſt ut tranſitus ſanguinis ab uno ad alterum cordis ventriculum interceptus, non multò pòſt ſiſtatur. Ceſſatio autem ſanguinis, Mors eſt. Poſſunt tamen animalia ceſſante ſanguine reviviſcere, ſi Aer externus ſatis maturè intromittatur, vel ipſa in Aerem temperatum, antequam refrixerit ſanguis, extrahantur.*

This Explication is not probable enough, to oblige me to add any thing about it to what I have ſaid in the 49th and the two following pages of my *Examen*; eſpecially the moſt vehement motion, aſcrib'd to the Air in the Receiver, having been before proved to be an Imaginary thing. You may therefore, if you pleaſe, take notice of the next Explication.

[*Idem Aer* (ſays he) *in Recipiente Carbones ardentes extinguit, ſed & illi, ſi, dum ſatis calidi ſunt, eximantur, relucebunt. Notiſſimum eſt, quòd in fodinis Carbonum terreorum (cujus rei ex-*

perimentum ipſe vidi) ſæpiſſime è lateribus foveæ ventus quidam undiquaque exit, qui foſſores interficit ignemque extinguit, qui tamen reviviſcunt ſi ſatis cito ad Aerem liberum extrahantur.]

This Compariſon which Mr. *Hobbes* here ſummarily makes, he more fully diſplay'd in his Dialogue *De Natura Aeris*, and I conſider'd, what he there alledg'd, in the 52th page and the two next of my *Examen*. And, though I will not contradict Mr. *Hobbes* in what he hiſtorically aſſerts in this paſſage; yet I cannot but ſomewhat doubt, whether he mingles not his conjecture with the bare matter of fact. For, though I have with ſome curioſity viſited Mines in more places than one, and propos'd Queſtions to Men that have been converſant in other Mines, both elſewhere and in *England* (and particularly in *Derbyſhire* where Mr. *Hobbes* lived long;) yet I could never find, that any ſuch odd and vehement wind, as Mr. *Hobbes* aſcribes the Phænomenon to, had been

been by them obſerved to kill the Diggers, and extinguiſh well-lighted Coals themſelves: And indeed, it ſeems more likely, that the damp, by its tenacity or ſome peculiarly malign quality, did the miſchief, than a wind, of which I found not any notice taken; eſpecially ſince we ſee, what vehement winds Men will be able to endure for a long time, without being near-kill'd by them; and that it ſeems very odd, that a wind, that Mr. *Hobbes* does not obſerve to have blown away the Coals, that were let down, ſhould be able (inſtead of kindling them more fiercely) to blow them *out*.

A. The laſt Experiment of your Engine, that your Adverſary mentions in theſe Problems, is deliver'd in this paſſage:

A. *Si phialam aquæ in Recipiens dimiſeris, exucto Aere bullire videbis aquam. Quid ad hoc Reſpondebis?*

B. *Credo ſanè in tanta Aeris motitatione ſaltaturam eſſe aquam, ſed ut caleſiat nondum audivi. Sed imagina-*

bile non eſt, Saltationem illam à Vacuo naſci poſſe.

B. This Phænomenon he likewiſe took notice of, and attempted to explicate in his above-mention'd Dialogue, which gave me occaſion in the 46th and 47th pages of my *Examen*, to ſhew how unlikely 'tis, that the vehement motion of the Air ſhould be the cauſe of it; but he here tells us, that 'tis not imaginable, that this dancing of the water (as he is pleas'd to call it) proceeds from a *vacuum*, nor do I know any Man that ever pretended, that a *vacuum* was the efficient cauſe of it. But the *Vacuiſts* perhaps will tell him, that, though the bubbling of the water be not an *effect* of a *vacuum*, it may be a *proof* of it againſt him; for they will tell him, that it has been formerly proved, that a great part of the Atmoſpherical Air is by pumping remov'd out of our exhauſted Receiver, and conſequently can no more, as formerly, preſs upon the ſurface of the water. Nor does Mr. *Hobbes* ſhew

ſhew what ſucceeds in the room of it; and therefore it will be allowable, for them to conclude againſt him (though not perhaps againſt the *Carteſians*) that there are a great many interſpers'd Vacuities left in the Receiver, which are the occaſion, though not the proper efficient cauſe, of the Phænomenon. For they will ſay, that the Springy Particles of the yet included Air, having room to unbend themſelves in the ſpaces deſerted by the Air that was pumpt out, the Aerial and Springy Corpuſcles, that lay conceal'd in the pores of the water, being now freed from the wonted preſſure that kept them coil'd up in the liquor, expanded themſelves into numerous bubbles, which, becauſe of their comparative lightneſs, are extruded by the water, and many of them appear to have riſen from the bottom of it. And Mr. *Hobbes*'s vehement wind, to produce the ſeveral Circumſtances of this Experiment, muſt be a laſting one. For, after the agitation of the Pump has been

been quite left off, provided the external Air be kept from getting in, the bubbles will ſometimes continue to riſe for an hour after. And that which agrees very well with our Explication and very ill with that of Mr *Hobbes*'s, is, that, when by having continued to pump a competent time, the water has been freed from the Aerial particles that lurk'd in it before, though one continue to pump as luſtily as he did, yet the water will not at all be cover'd with bubbles as it was, the Air that produc'd them being ſpent; though, according to Mr. *Hobbes*'s Explication, the wind in the Receiver continuing, the dance of the water ſhould continue too.

A. I eaſily gheſs, by what you have ſaid already, what you may ſay of that *Epiphonema* wherewith Mr. *Hobbes* (in his 18th page) concludes the Explications of the Phænomena of your Engine. [*Spero jam te certum eſſe*, ſays he, *nullum eſſe Machinæ illius Phænomenon, quo demonſtrari poteſt ullum in Univerſo locum dari corpore omni vacuum.*]

B. If

B. If you gheſs'd aright, you gheſs'd that I would ſay, that as to the Phænomena of my Engine, my buſineſs was to prove, that he had not ſubſtituted good Explications of them in the place of mine, which he was pleaſed to reject. And as for the proving a *Vacuum* by the Phænomena of my Engine, though I declar'd that was not the thing intended, yet I ſhall not wonder, that the *Vacuiſts* ſhould think thoſe Phænomena give them an advantage againſt Mr. *Hobbes.* For, though in the paſſage recited by you he ſpeak more cautiouſly than he is wont to do, yet, by what you may have already obſerv'd in his Argumentations, the way he takes to ſolve the Phænomena of our Engine, is by contending, that our Receiver, when we ſay it is almoſt exhauſted, is as full as ever (for he will have it *perfectly* full,) of common Air; which is a conceit ſo contrary to I know not how many Phænomena, that I do not remember I have met with or heard

heard of any Naturaliſt, whether Vacuiſt or Pleniſt, that having read my Phyſico-Mechanical Experiments and his Dialogue, has embrac'd his opinion.

A. After what you have ſaid, I will not trouble you with what he ſubjoyns about *Vacuum* in general, where having made his Academian ſay, [*Mundum ſcis finitum eſſe, & per Conſequens vacuum eſſe oportere totum illud Spatium quod eſt extra mundum infinitum. Quid impedit quo minus vacuum illud cum Aere mundano permiſceatur?*] He anſwers: *De rebus tranſmundanis nihil ſcio.* For I know, that it concerns not you to take notice of it. But poſſibly the *Vacuiſts* will think, he fathers upon them an Impropriety they would not be guilty of, making them ſpeak, as if they thought, the *ultra-mundan Vacuum* were a real Subſtance that might be brought into this World and mingled with our Air. And ſince, for ought I know, Mr. *Hobbes* might have ſpar'd this paſſage, if he had not deſign'd

ſign'd it ſhould introduce the ſlighting anſwer he makes to it; I ſhall add, that by the account Mr. *Hobbes* has given of ſeveral Phænomena *within* the World, 'tis poſſible, that the Vacuiſts may believe his Profeſſion of knowing nothing of things *beyond* it.

After the *Experimenta Boyliana* (as your other Adverſary calls them;) Mr. *Hobbes* proceeds to the Torricellian Experiment, of which he thus diſcourſes:

A. *Quid de experimento cenſes Torricelliano, probante Vacuum per Argentum vivum hoc modo: eſt in ſeq. figura ad* A, *pelvis ſive aliud vas, & in eo Argentum vivum uſque ad* B; *eſt autem* C D *tubus vitreus concavus repletus quoque Argento vivo. Hunc tubum ſi digito obturaveris erexeriſque in vaſe* A, *manumque abſtuleris, deſcendet Argentum vivum à* C; *verùm non effundetur totum in pelvim, ſed ſiſtetur in diſtantia quadam, puta in* D. *Nonne ergo neceſſarium eſt, ut pars tubi inter* C & D *ſit vacua? Non enim puto negabis quin*

quin ſuperficies tubi concava & Argenti vivi convexa ſe mutuo exquiſitiſſimè contingant.

B. *Ego neque nego contactum, neque vim Conſequentiæ intelligo.*

By which paſſage it ſeems that he ſtill perſiſts in the ſolution of this Experiment, which he gave in his Dialogue *De Natura Aeris*, and formerly did, for the main, either propoſe, or adopt, in his Elements of Philoſophy.

B. This opinion or explication of Mr. *Hobbes* I have, as far as concerns me, conſider'd in the 36th, and ſome inſuing pages, of my *Examen*, to which it may well ſuffice me to refer you. But yet let me take notice of what he now alledges:

B. *Si quis* (ſays he) *in Argentum vivum, quod in vaſe eſt, veſicam immerſerit inflatam, nonne illa amotâ manu emerget?*

A. *Ita certè, etſi eſſet veſica ferrea vel ex materia quacunque præter Aurum.*

B. *Vides igitur ab Aere penetrari poſſe Argentum vivum.*

A. *Etiam,*

A. *Etiam, & quidem illâ ipsâ vi quam à pondere accipit Argenti vivi.*

I confeſs this Allegation did a little ſurprize me: It concern'd Mr. *Hobbes* to prove, that as much Air, as was diſplac'd by the deſcending Mercury, did at the orifice of the Tube, immers'd in ſtagnant Mercury, inviſibly aſcend to the upper part of the pipe. To prove this he tells us, that a bladder full of Air being depreſs'd in Quickſilver, will, when the hand that depreſs'd it is remov'd, be ſqueez'd up by the very weight of the Mercury, whence it follows, that Air may penetrate Quickſilver. But I know not, who ever deny'd, that Air inviron'd with Quickſilver may thereby be ſqueez'd upwards; but, ſince even very ſmall bubbles of Air may be ſeen to move in their paſſage through Mercury, I ſee not, how this Example will at all help the Propoſer of it. For 'tis by meer accident, that the Air included in the bladder comes to be buoy'd up, becauſe the bladder it ſelf is ſo; and if it

it were fill'd with Water inſtead of Air, or with Stone inſtead of Water, it would nevertheleſs emerge, as himſelf confeſſes it would do, if it were made of Iron, or of any Matter beſides Gold, becauſe all other Bodies are lighter *in ſpecie* than Quickſilver. But ſince the emerſion of the bladder is manifeſt enough to the ſight, I ſee not how it will ſerve Mr. *Hobbes*'s turn, who is to prove that the Air gets into the Torricellian Tube inviſibly; ſince 'tis plain, that even heedful obſervation can make our Eyes diſcover no ſuch trajection of the Air; which (to add that inforcement of our Argument) muſt not only paſs unſeen through the ſuſtained Quickſilver, but muſt likewiſe unperceivedly dive, in ſpite of its comparative lightneſs, beneath the ſurface of the ponderous ſtagnant Mercury, to get in at the orifice of the erected Tube. But let us, if you pleaſe, hear the reſt of his Diſcourſe about this Experiment.

A. Though it be ſomewhat prolix,

lix, yet, according to my cuſtom hitherto, I will give it you *verbatim.*

B. *Simul atque Argentum vivum deſcenderit ad* D, *altius erit in vaſe* A *quàm antè, nimirum plus erit Argenti vivi in vaſe quàm erat ante deſcenſum, tanto quantum capit pars tubi* C, D. *Tanto quoque minus erit Aeris extra tubum quàm ante erat. Ille autem Aer qui ab Argento vivo loco ſuo extruſus eſt, (ſuppoſitâ univerſi plenitudine) quò abire poteſt niſi ad eum locum, qui in tubo inter* C & D *à deſcenſu Argenti vivi relinquebatur? ſed quâ, inquies, viâ in illum locum ſucceſſurus eſt? Quà, niſi per ipſum corpus Argenti vivi Aerem urgentis? Sicut enim omne grave liquidum, ſui ipſius pondere, Aerem, quem deſcendendo premit, aſcendere cogit (ſi via alia non detur) per ſuum ipſius corpus; ita quoque Aerem quem premit aſcendendo, (ſi via alia non detur) per ſuum ipſius corpus tranſire cogit. Manifeſtum igitur eſt, ſuppoſitâ mundi plenitudine poſſe Aerem externum ab ipſa gravitate Argenti vivi cogi in locum illum inter* C & D. *Itaque Phænomenon illud neceſſitatem vacui non*

demonſtrat. Quoniam autem corpus Argenti vivi penetrationi, quæ ſit ab Aere, non nihil reſiſtit, & aſcenſioni Argenti vivi in vaſe A *reſiſtit Aer; quando illæ duæ reſiſtentiæ æquales erunt, tunc in tubo ſiſtetur alicubi Argentum vivum; atque ibi eſt* D.

B. In anſwer to this Explication I have in my *Examen* propos'd divers things, which you may there meet with: And indeed his Explication has appear'd ſo improbable to thoſe that have written of this Experiment, that I have not found it embrac'd by any of them, though, when divers of them oppos'd it, the Phænomena of our Engine were not yet divulg'd. Not then needleſly to repeat what has been ſaid already, I ſhall on this occaſion only add one Experiment, that I afterwards made, and it was this: Having made the Torricellian Experiment (in a ſtraight Tube) after the ordinary way, we took a little piece of a fine Bladder, and raiſing the Pipe a little in the ſtagnant Mercury, but not ſo high

as

as the ſurface of it, the piece of Bladder was dexterouſly conveyed in the Quickſilver, ſo as to be applied by ones finger to the immerſed orifice of the Pipe, without letting the Air get into the Cavity of it; then the Bladder was tyed very ſtraight and carefully to the lower end of the Pipe, whoſe orifice (as we ſaid) it cover'd before, and then the Pipe being ſlowly lifted out of the ſtagnant Mercury, the impendent Quickſilver appear'd to lean but very lightly upon the Bladder, being ſo near an exact Æquilibrium with the Atmoſperical Air, that, if the Tube were but a very little inclin'd, whereby the gravitation of the Quickſilver, being not ſo perpendicular, came to be ſomewhat leſſen'd, the Bladder would immediately be driven into the orifice of the Tube, and to the Eye, plac'd without, appear to have acquir'd a concave ſuperficies inſtead of the convex it had before. And when the Tube was re-erected, the Bladder would no longer appear

ſuck'd in, but be again ſomewhat protuberant. And if, when the Mercury in the Pipe was made to deſcend a little below its ſtation into the ſtagnant Mercury, if, I ſay, at that nick of time the piece of Bladder were nimbly and dexterouſly apply'd, as before, to the immers'd orifice, and faſten'd to the ſides of the Pipe, upon the lifting the Inſtrument out of the ſtagnant Mercury, the Cylinder of that Liquor being now ſomewhat ſhort of its due height, was no longer able fully to counterpoiſe the weight of the Atmoſpherical Air, which conſequently, though the Glaſs were held in an erected poſture, would preſs up the Bladder into the orifice of the Pipe, and both make and maintain there a Cavity ſenſible both to the Touch and the Eye.

A. What did you mainly drive at in this Experiment?

E. To ſatisfie ſome Ingenious Men, that were more diffident of, than skilful in, Hydroſtaticks, that the

the preſſure of the external Air is capable of ſuſtaining a Cylinder of 29 or 30 Inches of Mercury, and upon a ſmall leſſening of the gravitation of that ponderous liquor, to preſs it up higher into the Tube. But a farther uſe may be made of it againſt Mr. *Hobbes*'s pretenſion. For, when the Tube is again erected, the Mercury will ſubſide as low as at firſt, and leave as great a ſpace as formerly was left deſerted at the top; into which how the Air ſhould get to fill it, will not appear eaſie to them, that, like you and me, know by many tryals, that a Bladder will rather be burſt by Air than grant it paſſage. And if it ſhould be pretended, *either* that ſome Air from without had yet got through the Bladder, *or* that the Air, that they may preſume to have been juſt before included between the Bladder and the Mercury, made its way from the lower part of the Inſtrument to the upper; 'tis obvious to anſwer, That 'tis no way likely, that it ſhould paſs all along the Cylinder

linder unſeen by us; ſince, when there are really any Aerial Bubbles, though ſmaller than Pins heads, they are eaſily diſcernible. And in our caſe, there is no ſuch reſiſtance of the Air to the aſcenſion of the ſtagnant Mercury, as Mr. *Hobbes* pretends in the Torricellian Experiment made the uſual way.

A. But, whatever becomes of Mr. *Hobbes*'s Explication of the Phænomenon; yet may not one ſtill ſay, that it affords no advantage to the *Vacuiſts* againſt him?

B. Whether or no it do againſt other *Pleniſts*, I ſhall not now conſider; but I doubt, the *Vacuiſts* will tell Mr. *Hobbes*, that he is fain in two places of the Explication, we have read, to ſuppoſe the Plenitude of the World, that is, to beg the thing in queſtion, which 'tis not to be preſum'd they will allow.

A. But may not Mr. *Hobbes* ſay, that 'tis as lawful for him to ſuppoſe a *Plenum*, as for them to ſuppoſe a *Vacuum*.

B. I think he may juſtly ſay ſo; but 'tis like they will reply, that, in their way of explicating the Torricellian Experiment, they do not *ſuppoſe* a *Vacuum* as to Air, but *prove* it. For they ſhew a great ſpace, that having been juſt before fill'd with Quickſilver, is now deſerted by it, though it appeared not, that any Air ſucceeded in its room; but rather, that the upper end of the Tube is either totally or near totally ſo devoid of Air, that the Quickſilver may without reſiſtance, by barely inclining the Tube, be made to fill it to the very top: Whereas Mr. *Hobbes* is fain to have recourſe to that which he knows they deny, the Plenitude of the World, not proving by any ſenſible Phænomena, that there *did* get in through the Quickſilver Air enough to fill the deſerted part of the Tube, but only concluding, that ſo much Air *muſt* have got in there, becauſe, the World being full, it could find no room any where elſe; which the *Vacuiſts* will take for no

proof at all, and the *Carteſians*, though *Pleniſts*, who admit an Etherial matter capable of paſſing through the pores of Glaſs, will, I doubt, look upon but as an improper Explication.

A. I remember on this occaſion another Experiment of yours, that ſeems unfavourable enough to Mr. *Hobbes*'s Explication, and you will perhaps call it to mind when I tell you, that 'twas made in a bended Pipe almoſt fill'd with Quickſilver.

B. To ſee whether we underſtand one another, I will briefly deſcribe the Inſtrument I think you mean. We took a Cylindrical Pipe of Glaſs, clos'd at the upper end, and of that length, that being dexterouſly bent at ſome Inches from the bottom, the ſhorter legg was made as parallel as we could to the longer: In this Glaſs we found an expedient, (for 'tis not eaſie to do,) to make the Torricellian Experiment, the Quickſilver in the ſhorter legg ſerving inſtead of the ſtagnant Quickſilver in the uſual Baroſcope, and the Quickſilver in the longer

longer legg reaching above that in the ſhorter about eight or nine and twenty Inches. Then, by another artifice, the ſhorter legg, into which the Mercury did not riſe within an Inch of the top, was ſo order'd, that it could in a trice be Hermetically ſeal'd, without diſordering the Quick-ſilver. And this is the Inſtrument that I gheſs you mean.

A. It is ſo, and I remember, that it is the ſame with that, which in the Paradox about Suction you call, whilſt the ſhorter legg remains unſeal'd, a *Travelling Baroſcope.* But when I ſaw you make the Experiment, that legg was Hermetically ſeal'd, an Inch of Air in its natural or uſual conſiſtence being left in the upper part of it, to which Air you outwardly applied a pair of heated Tongs.

B. Yet that, which I chiefly aim'd at in the Trial, was not the Phænomenon I perceive you mean; for, my deſign was, by breaking the Ice for them, to encourage ſome, that may have

have more skill and accommodation than I then had, to make an attempt that I did not find to have been made by any; namely, to reduce the Expanſive force of Heat in every way included Air, if not in ſome other Bodies alſo, to ſome kind of meaſure, and, if 'twere poſſible, to determin it by weight. And I preſumed, that at leaſt the event of my Tryal would much confirm ſeveral Explications of mine, by ſhewing, that Heat is able, as long as it laſts, very conſiderably to increaſe the Spring or preſſing power of the Air. And in this conjecture I was not miſtaken; for, having ſhut up, after the manner newly recited, a determinate quantity of uncompreſt Air, which, (in the Experiment you ſaw,) was about one Inch; we warily held a pair of heated Tongs near the outſide of the Glaſs, (without making it touch the Inſtrument, for fear of breaking it,) whereby the Air being agitated was enabled to expand it ſelf to double its former Dimenſions, and conſequently

quently had its Spring ſo ſtrengthen'd by Heat, that it was able to raiſe all the Quickſilver in the longer legg, and keep up or ſuſtain a Mercurial Cylinder of about nine and twenty Inches high, when by its expanſion it would, if it had not been for the Heat, have loſt half the force of its elaſticity. But whatever I deſign in this Experiment, pray tell me, what uſe you would make of it againſt Mr. *Hobbes.*

A. I believe, he will find it very difficult to ſhew, what keeps the Mercury ſuſpended in the longer legg of the *Travelling Baroſcope*, when the ſhorter legg is unſtopt, at which it may run out; ſince this Inſtrument may, as I have try'd, be carried to diſtant places, where it cannot with probability be pretended, that any Air has been diſplac'd by the fall of the Quickſilver in the longer legg, which perhaps fell long before above a mile off. And when the ſhorter legg is ſeal'd, it will be very hard for Mr. *Hobbes* to ſhew there the odd motions

motions of the Air, to which he aſcribes the Torricellian Experiment. For, if you warily incline the Inſtrument, the Quickſilver will riſe to the top of the longer legg, and immediately ſubſide, when the Inſtrument is again erected, and yet no Air appears to paſs through the Quickſilver interpos'd between the ends of the longer and the ſhorter legg. But that which I would chiefly take notice of in the Experiment, is, that upon the external application of a hot Body to the ſhorter legg of the Baroſcope, when 'twas ſeal'd up, the included Air was expanded from one Inch to two, and ſo rais'd the whole Cylinder of Mercury in the longer legg, and, whilſt the heat continued undiminiſhed, kept it from ſubſiding again. For, if the Air were able to get unſeen through the body of the Quickſilver, why had it not been much more able, when rarified by Heat, to paſs through the Quickſilver, than for want of doing ſo to raiſe and ſuſtain ſo weighty a Cylinder

der of Mercury? I ſhall not ſtay to inquire on this occaſion, how Mr. *Hobbes* will, according to his *Hypotheſis*, explicate the rarefaction of the Air to double its former dimenſions, and the condenſation of it again; eſpecially ſince, aſſerting that part of the upper legg, that is unfill'd with the Quickſilver, to be perfectly full of Air, he affirms that, which I doubt he cannot prove, and which may very probably be diſproved by the Experiment you mention in the Diſcourſe about *Suction*, where you ſhew, to another purpoſe, that in a *Travelling Baroſcope*, whoſe ſhorter legg is ſeal'd, if the end of the longer legg be open'd, whereby it comes *indeed* to be fill'd with Air, the preſſure of that Air will enable the ſubjacent Mercury notably to compreſs the Air included in the ſhorter legg.

B. I leave Mr. *Hobbes* to conſider what you have objected againſt his Explication of the Torricellian Experiment; to which I ſhall add nothing,

thing, though perhaps I could add much, becauſe I think it may be well ſpared, and our Conference has laſted long already.

A. I will then proceed to the laſt Experiment recited by Mr. *Hobbes* in his *Problemata de Vacuo.*

A. *Si Phialam, collum habentem longiuſculum, eandémque omni Corpore præter Aerem vacuam ore ſugas, continuoque Phialæ os aquæ immergas, videbis aquam aliquouſque aſcendere in Phialam. Quî fieri hoc poteſt niſi factum ſit Vacuum ab exuctione Aeris, in cujus locum poſſit Aqua illa aſcendere?*

B. *Conceſſo Vacuo, oportet quædam loca vacua fuiſſe in illo Aere, etiam qui erat intra Phialam ante ſuctionem. Cur ergo non aſcendebat Aqua ad ea implenda abſque ſuctione? Is qui ſugit Phialam, neque in ventrem quicquam, neque in pulmones, neque in os è Phiala exugit. Quid ergo agit? Aerem commovet, & in partibus ejus conatum ſugendo efficit per os exeundi, & non admittendo, conatum redeundi. Ab his conatibus contrariis componitur circumitio intra Phialam.*

Phialam, & conatus exeundi quaquaversum. Itaque Phialæ ore aquæ immerso, Aer in subjectam aquam penetrat è Phiala egrediens, & tantundem aquæ in Phialam cogit.

Præterea vis illa magna ſuctionis facit, ut ſugentis labra cum collo Phialæ aliquando arctiſſimè cohæreant propter contactum exquiſitiſſimum.

B. As to the firſt Clauſe of Mr. *Hobbes*'s account of our Phænomenon, the *Vacuiſts* will eaſily anſwer his Queſtion by acknowledging, that there were indeed interſpers'd Vacuities in the Air contain'd in the Vial before the ſuction; but they will add, there was no reaſon, why the Water ſhould aſcend to fill them, becauſe, being a heavy body, it cannot riſe of it ſelf, but muſt be raiſed by ſome prevalent weight or preſſure, which then was wanting. Beſides, that there being interſpers'd Vacuities as well in the reſt of the Air that was very near the Water, as in that contained in the Vial, there was no reaſon, why the Water ſhould

ſhould aſcend to fill the Vacuities of one portion of Air rather than thoſe of another. But when once by ſuction a great many of the Aerial Corpuſcles were made to paſs out of the Vial, the Spring of the remaining Air being weaken'd, whilſt the preſſure of the ambient Air, which depends upon its conſtant Gravity, is undiminiſhed, the Spring of the internal becomes unable to reſiſt the weight of the external Air, which is therefore able to impel the interpos'd Water with ſome violence into the Cavity of the Glaſs, 'till the Air, remaining in that Cavity, being reduced almoſt to its uſual Denſity, is able by its Spring, and the weight of the Water got up into the Vial, to hinder any more Water from being impell'd up. For, as to what Mr. *Hobbes* affirms, that, *Is qui ſugit Phialam neque in ventrem quicquam, neque in pulmones, neque in os quicquam exugit* : How it will agree with what he elſewhere delivers about Suction. I leave him to conſider.

But I confeſs, I cannot but wonder at his confidence, that can poſitively aſſert a thing ſo repugnant to the common ſentiments of Men of all opinions, without offering any proof for it. But I ſuppoſe, they that are by tryal acquainted with Sucking, and have felt the Air come in at their mouths, will prefer their own experience to his authority. And as to what he adds, that the Perſon that ſucks agitates the Air, and turns it within the Vial into a kind of circulating wind, that endeavours every where to get out; I wiſh, he had ſhewn us by what means a Man that ſucks makes this odd Commotion of the Air; eſpecially in ſuch Vials as I uſe to employ about the Experiment, the orifice of whoſe neck is ſometimes leſs than a Pins head.

A. That there may be really Air extracted by Suction out of a Glaſs, me thinks you might argue from an Experiment I ſaw you make with a Receiver which was exhauſted by your Pump, and conſequently by Su-

ction. For I remember, when you had counterpois'd it with very good Scales, and afterwards by turning a ſtop-cock, let in the outward Air, there ruſh'd in as much Air to fill the ſpace that had been delerted by the Air pumpt out, as weighed ſome ſcruples (conſiſting of twenty grains a piece) though the Receiver were not of the largeſt ſize.

B. You did well to add that Clauſe; for, the *Magdeburgic* Experiment, mentioned by the induſtrious *Schottus*, having been made with a vaſt Receiver, the readmitted Air amounted to a whole ounce and ſome drachms. But to return to Mr. *Hobbes*, I fear not that he will perſwade you, that have ſeen the Experiment he recites; that as ſoon as the neck of the Vial is unſtopt under water, the Air, that whirl'd about before, makes a ſally out, and forces in as much water. For, if the orifice be any thing large, you will, inſtead of feeling an endeavour to thruſt away your finger that ſtopt it, find the pulp of your

your finger ſo thruſt inward, that a *Peripatetick* would affirm that he felt it ſuckt in. And that Intruſion may be the Reaſon, why the lip of him that ſucks is oftentimes ſtrongly faſten'd to the orifice of the Vials neck, which Mr. *Hobbes* aſcribes to a moſt exquiſit contact, but without clearly telling us, how that extraordinary contact is effected. And when your finger is removed, inſtead of perceiving any Air go out of the Vial through the water, (which, if any ſuch thing happen, you will eaſily diſcover by the bubbles,) you ſhall ſee the water briskly ſpring up in a ſlender ſtream to the top of the Vial, which it could not do, if the Cavity were already full of Air. And to let you ſee, that, when the Air does really paſs in or out of the Vial immers'd under water, 'tis very eaſie to perceive its motions, if you dip the neck of the Vial in water, and then apply to the globulous part of it either your warm hands or any other competent Heat, the internal

Air being rarified; you ſhall ſee a portion of it, anſwerable to the degree of Heat you applied, manifeſtly paſs through the water in ſucceſſive bubbles, whilſt yet you ſhall not ſee any water get into the Vial to ſupply the place deſerted by that Air. And if, when you have (as you may do by the help of ſucking) fill'd the neck and part of the belly of the Vial with water, you immerſe the orifice into ſtagnant water, and apply warm hands to the globulous part as before, you will find the water in the Vial to be driven out, before any bubbles paſs out of the Vial into the ſurrounding water; which ſhews, that the Air is not ſo forward to dive under the water, (and much leſs under ſo ponderous a liquor as Quick-ſilver,) as Mr. *Hobbes* has ſuppoſed.

A. That 'tis the Preſſure of the external Air, that (ſurmounting the Spring of the internal) drives up the water into the Vial we have been ſpeaking of, does, I confeſs, follow upon your Hypotheſis: But an Experimen-

rimentarian Philoſopher, as Mr. *Hobbes* calls you among others, may poſſibly be furniſhed with an Experiment to confirm this to the Eye.

B. You bring into my mind what I once deviſed to confirm my Hypotheſis about Suction, but found a while ſince that I had omitted it in my Diſcourſe about that Subject. And therefore I ſhall now repeat to you the ſubſtance at leaſt of the Memorial that was written of that Experiment, by which the great intereſt of the weight of the Atmoſpherical Air in Suction will appear, and in which alſo ſome things will occur, that will not well agree with Mr. *Hobbes*'s Explication, and prevent ſome of his Allegations againſt mine.

A. Having not yet met with an Experiment of this nature, ſuch an one as you ſpeak of will be welcome to me.

B. We took a Glaſs Bubble, whoſe long ſtem was both very ſlender and very Cylindrical; then by applying

to the outſide of the Ball or globulous part a convenient heat, we expell'd ſo much of the Air, as that, when the end of the pipe was dipt in water, and the inward Air had time to recover its former coolneſs, the water aſcended either to the top of the pipe or very near it. This done, we gently and warily rarified the Air in the Cavity of the Bubble, 'till by its expanſion it had driven out almoſt all the water that had got up into the ſtem, that ſo it might attain as near as could be to that degree of heat and meaſure of expanſion, that it had when the water began to riſe in it. And we were careful to leave two or three drops of water unexpell'd at the bottom of the pipe, that we might be ſure, that none of the included Air was by this ſecond rarefaction driven out at the orifice of it; as the depreſſion of the water ſo low aſſured us, on the other ſide, that the included Air wanted nothing conſiderable of the expanſion it had when the water began to aſcend into

the

the pipe. Whilſt the Air was in this rarified ſtate, we preſently removed the little Inſtrument out of the ſtagnant water into ſtagnant Quickſilver, which in a ſhort time began to riſe in the pipe. Now, if the aſcenſion of the liquor were the effect of Natures Abhorrence of a *Vacuum*; or of ſome internal principle of Motion; or of the Compreſſion and propagated Pulſion of the outward Air by that which had been expell'd; why ſhould not the Mercury have aſcended to the top of the pipe, as the water did before? But *de facto* it did not aſcend half, or perhaps a quarter ſo far; and if the pipe had been long enough, as well as 'twas ſlender enough, I queſtion, whether the Mercury would have aſcended (in proportion to the length of the ſtem) half ſo high as it did.

Now of this Experiment, which we tryed more than once, I ſee not, for the reaſon lately expreſs'd, how any good account will be given without our *Hypotheſis*, but according to *That* 'tis clear.

A. I think I perceive why you ſay ſo; for the Aſcenſion of Liquors being an effect of the prevalency of the external Airs preſſure againſt the reſiſtance it meets with in the Cavity of the Inſtrument, and the Quickſilver being bulk for bulk many times heavier than water, the ſame ſurpluſage of preſſure that was able to impel up water to the top of the pipe, ought not to be able to impel up the Quickſilver to any thing near that height. And if it be here objected, as it very plauſibly may be, that the raiſed Cylinder of Mercury was much longer than it ought to have been in reference to a Cylinder of Water, the proportion in gravity between thoſe two Liquors (which is almoſt that of fourteen to one) being conſidered; I anſwer, that when the Cylinder of Water reach'd to the pipe, the Air poſſeſs'd no more than the Cavity of the globulous part of the Inſtrument, being very little aſſiſted to dilate it ſelf by ſo light a Cylinder as that of Water: But when the

the Quickſilver came to be impell'd into the Inſtrument by the weight of the external Air, that ponderous Body did not ſtop its aſcent as ſoon as it came to be equiponderant to the formerly expell'd Cylinder of Water; becauſe, to attain that height, it reached but a little way into the pipe, and left all the reſt of the Cavity of the pipe to be fill'd with part of that Air, which formerly was all ſhut up in the Cavity of the Bubble; by which means the Air, included in the whole Inſtrument, muſt needs be in a ſtate of expanſion, and thereby have its Spring weakened, and conſequently diſabled to reſiſt the preſſure of the external Air, as much as the ſame included Air did before, when it was leſs rarified; on which account, the undiminiſhed weight or preſſure of the external Air was able to raiſe the Quickſilver higher and higher, 'till it had obtained that height, at which the preſſure, compounded of the weight of the Mercurial Cylinder and the Spring of the internal

internal Air (now leſs rarified than before,) was equivalent to the preſſure of the Atmoſphere or external Air.

B. You have given the very Explication I was about to propoſe; wherefore I ſhall only add, that, to confirm this Experiment by a kind of Inverſion of it, we drove by heat a little Air out of the Bubble, and dipt the open end of the pipe into Quickſilver, which by this means we made to aſcend 'till it had fill'd about a fourth part or leſs of the pipe, when that was held erected. Then carefully removing it without letting fall any Quickſilver, or letting in any Air, we held the orifice of the pipe a little under the ſurface of a Glaſs full of Water, and applying a moderate heat to the outſide of the Ball, we warily expell'd the Quickſilver, yet leaving a little of it to make it ſure that no Air was driven out with it; then ſuffering the included Air to cool, the external Air was found able to make the

Water

Water not only aſcend to the very top of the pipe, and thence ſpread it ſelf a little into the Cavity of the Ball, but to carry up before it the Quickſilver that had remained unexpell'd at the bottom of the ſtem. And if in making the Experiment we had firſt raiſed, as we ſometimes did, a greater quantity of Quickſilver, and afterwards drove it out, the quantity of Water, that would be impell'd into the Cavity of the pipe and ball, would be accordingly increaſed.

A. In this Experiment 'tis manifeſt, that ſomething is driven out of the Cavity of the Glaſs before the Water or Quickſilver begins to aſcend in it: And here alſo we ſee not, that the Air can paſs through the pores of Quickſilver or Water, but that it drives them on before it, without ſenſibly mixing with them. In this Experiment there appears not at all any Circular Wind, as Mr. *Hobbes* fancies in the ſuckt Vial we are diſputing of, nor any tendency outwards

of

of the included Air upon the account of ſuch a Wind; but, inſtead of theſe things, that the aſcenſion of the Liquors into the Cavity of the pipe depends upon the external Air, preſſing up the Liquors into that Cavity, may be argu'd by this, that the ſame weight of the Atmoſphere impell'd up into the pipe ſo much more of the lighter Liquor, *Water*, than of the heavier Liquor, *Mercury*.

B. You have ſaid enough on this Experiment; but 'tis not the only I have to oppoſe to Mr. *Hobbes* his Explication: For, that there is no need of the ſallying of Air out of a Vial, to make the Atmoſpherical Air preſs againſt a Body that cloſes the orifice of it, when the preſſure of the internal Air is much weakened; I have had occaſion to ſhew ſome *Virtuoſi*, by ſucking out, with the help of an Inſtrument, a conſiderable portion of the Air contained in a Glaſs; for having then, inſtead of unſtopping the orifice under water, nimbly applied a flat Body to it, the external Air preſs'd

that

that Body ſo forcibly againſt it, as to keep it faſtened and ſuſpended, though 'twere clogg'd with a weight of many ounces.

A. Another Experiment of yours Mr. *Hobbes*'s Explication brings into my mind, by which it appears, that, if there be ſuch a Circular Wind, as he pretends, produced by Suction in the Cavity of the Vial, it muſt needs be ſtrangely laſting. For I have ſeen more than once, that, when you have by an Inſtrument ſuckt much of the Air out of a Vial, and afterwards carefully cloſed it, though you kept the ſlender neck of it ſtopt a long time, perhaps for ſome weeks or months, yet when 'twas open'd under water, a conſiderable quantity of the Liquor would be briskly impell'd up into the neck and belly of the Vial. So that, though I will not be ſo pleaſant with Mr. *Hobbes*, as to mind you on this occaſion of thoſe Writers of Natural Magick, that teach us to ſhut up Articulate Sounds in a Veſſel, which being tranſported to a diſtant

place

place and open'd there, will render the Words that are committed to it; yet I muſt needs ſay, that ſo laſting a Circular Wind, as, according to Mr. *Hobbes*, your Experiments exhibited, may well deſerve our wonder.

B. Your admiration would perchance increaſe, if I ſhould aſſure you, that having with the Sun-beams produced ſmoak in one of thoſe well-ſtopt Vials, this Circular Wind did not at all appear to blow it about, but ſuffered it to riſe, as it would have done if the included Air had been very calm. And now I ſhall add but one Experiment more, which will not be liable to ſome of the things as invalid as they are, which Mr. *Hobbes* has alledged in his account of the Vial, and which will let you ſee, that the weight of the Atmoſpherical Air is a very conſiderable thing; and which may alſo incline you to think, that, whilſt Mr. *Hobbes* does not admit a ſubtiler Matter than common Air to paſs through the Pores of cloſe and ſolid Bodies, the Air he has recourſe to will ſome-

ſometimes come too late to prevent a *Vacuum*. The Experiment, which was partly accidental, I lately found regiſtred to this ſenſe, if not in theſe words: [Having, to make ſome Diſcovery of the weight of the Air, and for other purpoſes, caus'd an Æolipile, very light conſidering its bulk, to be made by a famous Artiſt, I had occaſion to put it ſo often into the fire for ſeveral Tryals, that at length the Copper ſcal'd off by degrees, and left the Veſſel much thinner than when it firſt came out of the Artificers hands; and a good while after, this change in the Inſtrument being not in my thoughts, I had occaſion to imploy it, as formerly, to weigh how many grains it would contain of the Air at ſuch a determinate conſtitution of the Atmoſphere, as was to be met with, where I then chanced to be. For the making this Experiment the more exactly, the Air was by a ſtrong, but warily applied, fire ſo carefully driven away, that, when clapping a piece of Sealing-wax to the Pin-hole, at which it had been forced out, we hindred any com-

communication betwixt the Cavity of the Inſtrument and the external Air, we ſuppos'd the Æolipile to be very well exhauſted, and therefore laid it by, that, when it ſhould be grown cold, we might, by opening the orifice with a Pin, again let in the outward Air, and obſerve the encreaſe of weight that would thereupon enſue: But the Inſtrument, that, as I was ſaying, was grown thin, had been ſo diligently freed from Air, that the very little that remain'd, and was kept by the Wax from receiving any aſſiſtance from without, being unable by its Spring to aſſiſt the Æolipile to ſupport the weight of the ambient Air; this external fluid did by its weight preſs againſt it ſo ſtrongly, that it compreſs'd it, and thruſt it ſo conſiderably inwards, and in more than one place ſo chang'd its figure, that, when I ſhew'd it to the *Virtuoſi* that were aſſembled at *Greſham-Colledge*, they were pleaſed to command it of me to be kept in their Repoſitory, where I preſume it is ſtill to be ſeen.

FINIS.

NEW
EXPERIMENTS
About the
PRESERVATION
OF
BODIES
IN
VACUO BOYLIANO.

By the Honourable
ROBERT BOYLE,
Fellow of the *Royal Society*.

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